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Ben-Zvi

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[54] **TRIAXIALLY PRESTRESSED POLYGONAL CONCRETE MEMBERS**

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[52] **U.S. Cl.** **52/223,** 52/2, 52/224, 52/724, 52/725, 52/731

[51] **Int. Cl.** **E04c 3/20,** E04c 3/26

[58] **Field of Search** 52/2, 724, 725, 727, 728, 52/731, 222, 223

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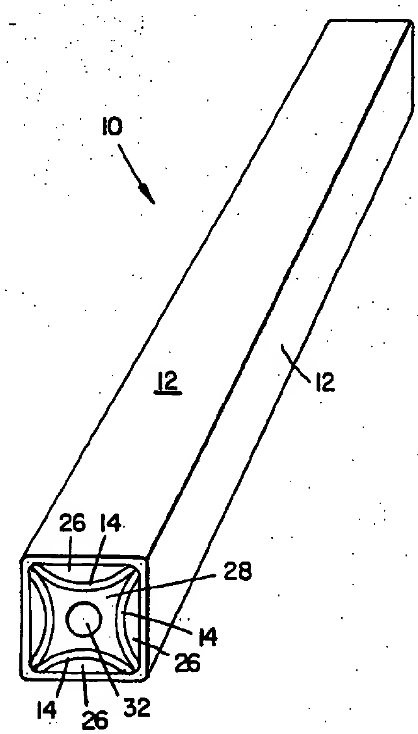
Assistant Examiner—H. E. Raduazo

[57] **ABSTRACT**

A triaxially prestressed concrete member having a polygonal cross-section is disclosed. The member includes an elongate hollow casing which has a polygonal, usually square or rectangular cross-section. Elongate arcuate liners are located within the casing and are co-extensive therewith. The opposite side lateral edges of each liner are in abutment with adjacent interior corners of the casing. These liners divide the hollow interior of the casing into at least three side sections defined by the concave surfaces of the respective arcuate liners and the interior surfaces of the casing, and a central section defined by the convex surfaces of the liners. Non-expansive concrete material fills the side portions of the casing, and expansive concrete material fills the central portion. The radial expansion of the expansive concrete is restrained by the arcuate liners which are in contact with the interior corners of the casing to radially or biaxially prestress the concrete. Longitudinal expansion of the expansive concrete material is prohibited by adherence of the concrete to the convex surfaces of the arcuate liners to prestress the concrete in a third triaxial direction.

14 Claims, 7 Drawing Figures



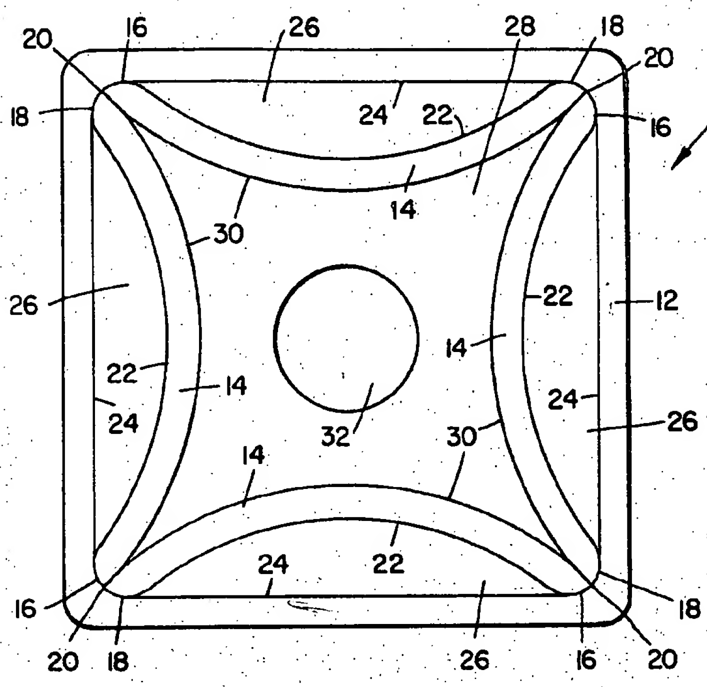


FIG_1A

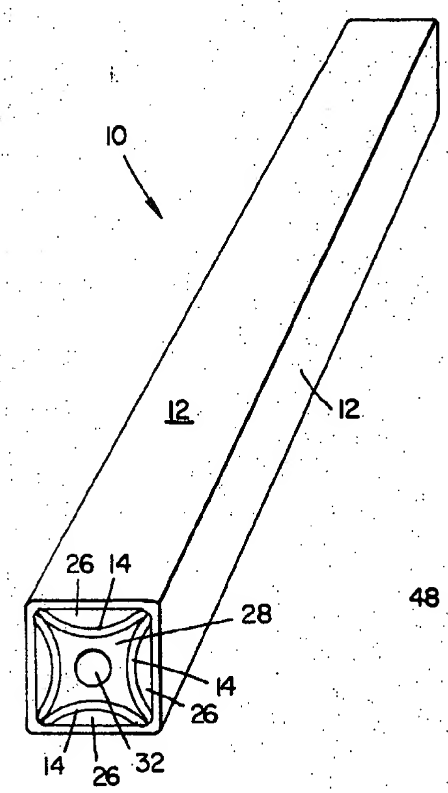


FIG_1B

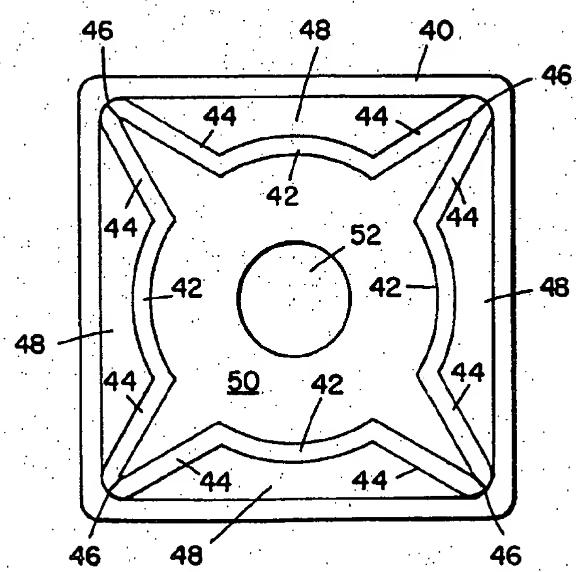


FIG_2

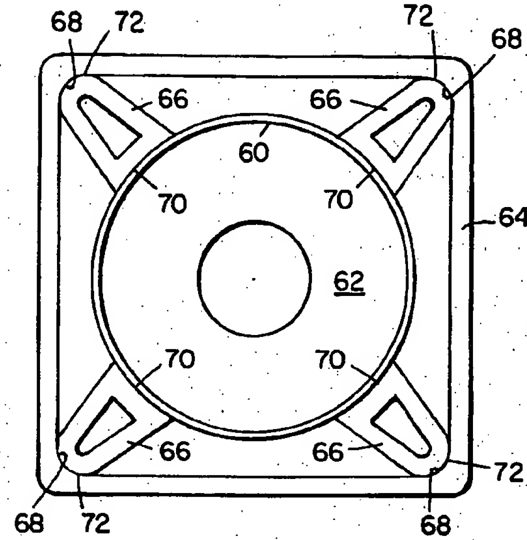


FIG_3

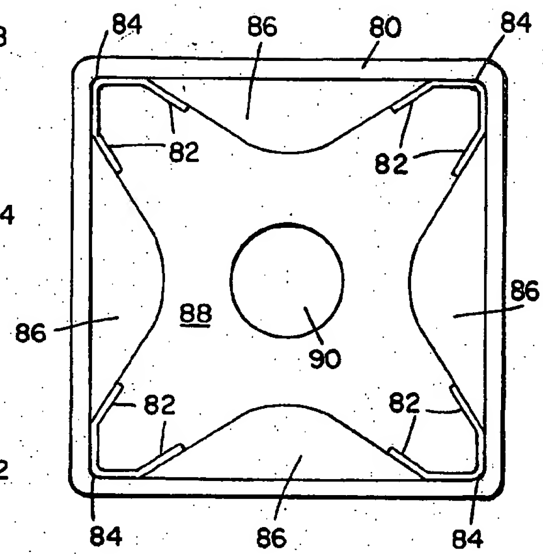


FIG_4

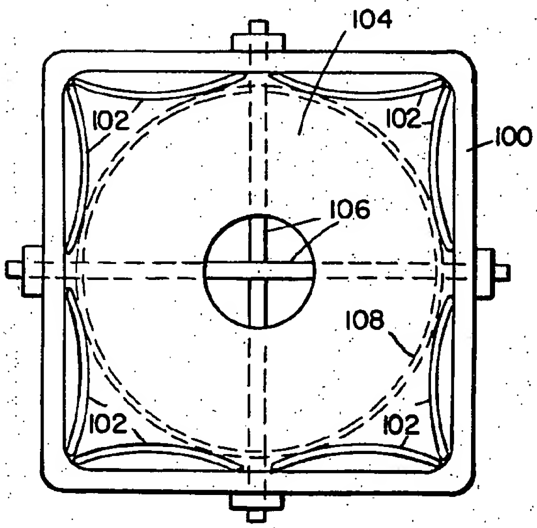


FIG_5

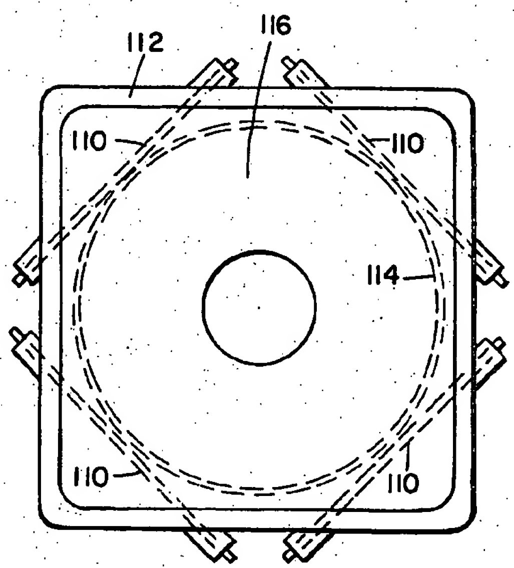


FIG_6

TRIAXIALLY PRESTRESSED POLYGONAL CONCRETE MEMBERS

BACKGROUND OF THE INVENTION

The present invention relates to concrete members, and in particular to triaxially prestressed concrete members which have a generally square or rectangular cross-section.

The advantages of biaxially prestressing vertical concrete construction members (columns) and triaxially prestressing horizontal concrete construction members (beams) are well known. Concrete under compression almost always fails normal to the direction of the load, and when a column is axially loaded, biaxial or radial prestressing greatly increases the load carrying capability of the column. Beams are subject to transverse loading as well as axial loading, and triaxial prestressing contributes considerably to the bearing capacity of the column and might reach strengths similar to solid steel columns.

The recent emphasis on constructing earthquake-proof structures in areas wherein earthquakes are likely to occur has resulted in the appreciation of a new advantage of square triaxially prestressing concrete members where the members are used as columns. In the past, it was felt that columns were subjected to virtually no transverse loading and triaxial prestressing was not necessary. However, during an earthquake, it has been found that the columns of the building will be subjected to significant transverse loading, and a triaxially confined round column does not show any preference in resisting transverse loading or eccentricities more than other non prestressed or non-confined columns. However, triaxially confined square or rectangular columns as described herein, should have considerable resistance to eccentric load due to the increased moment of inertia for the same area.

Two basic methods have been used heretofore to form triaxially prestressed concrete members. One is the so-called "active" method in which non-expansive concrete material is poured into a circular mold and allowed to mature. Wire is helically wound around the exterior of the matured concrete, and the wire is then tensioned to compress the concrete. Another method, often called the "passive" method, provides a helically wound wire inside a cylindrical form. Expansive concrete is then poured into the form, and during maturation of the concrete, the helical wires resist the expansion and biaxially prestress the concrete. Triaxial compression results from the axial load, or can be induced by means of tie-rods running the length of the concrete member and anchored at each end.

The problem with the above methods for forming triaxially prestressed concrete members is that the resulting member is necessarily cylindrical. Square members are highly desirable and even necessary in many applications. Square members are especially desirable for use as beams due to the increased transverse (bending) load carrying capability of a square member. Also, it is usually more simple to mount a floor or roof section on a square support member rather than a round member. Hence, even though triaxially prestressed concrete members are highly desirable in many applications, the fact that such members must be cylindrical has seriously impeded the use of such members in actual practice, even for direct compression.

SUMMARY OF THE INVENTION

The present invention relates to triaxially prestressed concrete members which have a generally square or other polygonal cross-section. The members comprise an elongate hollow casing which has a cross-section corresponding to the desired shape of the member. Elongate arcuate liners are preferably located within the casing and are co-extensive therewith. The opposite side lateral edges of each arcuate liner are in abutment with adjacent interior corners of the casing to divide the hollow interior of the casing into side sections defined by the concave surfaces of the respective arcuate liners and the interior surfaces of the casing. A central section is defined by the convex surfaces of the arcuate liners. Non-expansive concrete material is used to fill the side sections and expansive concrete material is used to fill the central section so that the expansive concrete is triaxially prestressed. Several alternative methods for achieving the objectives of the present invention are also disclosed.

The principle object of the present invention is to provide a triaxially prestressed concrete member which has a generally square or rectangular cross-section, although the system disclosed herein is applicable to any polygon shape. The system of arcuate liners in contact with the internal corners of the casing are forced radially outwardly by the expansive concrete. Such movement is prevented by the casing, and the attempted expansion of the expansive concrete is prevented by the presence of the casing so that the concrete is prestressed.

An advantage of the concrete member formed according to the teachings of the present invention is that the radial forces caused by the expansion of the concrete are counter-acted solely by tension forces in the casing so that the original shape of the casing is retained. Such a casing, preferably constructed of steel, is quite strong in tension, although it has little strength in compression, and the individual sidewalls have little resistance to bending. Hence, the primary strength of the casing is utilized to resist expansion and thereby prestress the concrete. It should be noted that if arcuate liners were not used to transmit the force to the corners of the casing, but rather expansive concrete were merely poured into the entire portion of the casing, the sides of the casing would merely bow out since the sidewalls of the casing have little bending resistance. The concrete would thus not be adequately prestressed, and the member would no longer be square.

Another advantage of a concrete member formed according to the teachings of the present invention is that a separate tie rod need not be used to prestress the member in the axial direction, the adherence of the concrete to the liners providing the desired axial prestress.

Still another advantage of the present invention is that the casing provides a form for the pouring of the concrete, and a separate removable form is not required.

The novel features which are believed to be characteristic of the invention, both as to organization and method of operation, together with further objects and advantages thereof will be better understood from the following description considered in connection with the accompanying drawings in which several preferred embodiments of the invention are illustrated by way of

example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are end and perspective views respectively of the preferred embodiment of the present invention;

FIG. 2 is an end view of one alternative embodiment of the present invention using W-shaped internal members;

FIG. 3 is an end view of another alternative embodiment of the present invention using a central tube and blocks;

FIG. 4 is an end view of another alternative embodiment of the present invention using removable internal forms;

FIG. 5 is an end view of still another embodiment of the present invention using bolts connecting opposite sides of the casing;

FIG. 6 is an end view of yet another embodiment of the present invention using bolts connecting adjacent sides of the casing.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiment of the present invention utilized to form a square concrete member **10** is illustrated by way of reference to FIGS. **1A** and **1B** in combination. Concrete member **10** includes an outer casing or sheath **12** having a substantially square cross-section. A plurality of individual arcuate liners **14** are mounted in the hollow interior of casing **12**, the length of the liners being co-extensive with the length of the casing. The opposite lateral edges **16, 18** of each liner are in abutment with the internal corners **20** of casing **12** along the entire length of the respective corners.

The concave interior surfaces **22** of each arcuate liner **14**, in combination with the interior surfaces **24** of the sidewalls of casing **12**, define a plurality of side channels **26** in the hollow interior of casing **12**. Side channels **26** can be filled with non-expansive concrete so that elongate arcuate liners **14** cannot buckle when loaded. The central channel **28** defined by the exterior or convex surfaces **30** of the arcuate liners **14** can then be filled with expansive concrete. A temporary core **32** or curing hole can be provided for curing of the concrete.

The expansive concrete poured into central channel **28** will attempt to expand as it matures. Although the term "expansive concrete" is used herein, the present invention relates to any expansive cementitious material used in making artificial stone structural components, and the term "expansive concrete" as used herein includes all such materials. Since the central channel is defined by the convex surfaces **30** of arcuate liners **14**, expansion of the concrete will attempt to move the liners radially outwardly. Since the lateral edges **16, 18** of arcuate liners **14** are in contact with the interior corners **20** of casing **12**, radial movement of the liners will be restrained by the casing at the internal corners thereof. Due to the shape of the arcuate liners, and the fact that such members are directed radially outwardly at the corners of the casing, the corners of the casing will attempt to expand radially outwardly. However, such expansion will be prevented by tension in the sidewalls of casing **12**, thus radially prestressing the expansive concrete in central channel **28** of casing **12**. Concrete in central channel **28** adheres to the convex surfaces **30** of arcuate liners **14** to axially prestress the concrete. After the expansive concrete has matured, the temporary curing hole **32** can be filled.

Since relatively strong tension forces are induced in the sidewalls of casing **12**, steel is the preferred casing material. However, other materials capable of withstanding the tension forces induced, such as fibreglass, could also be used. Arcuate liners **14** are primarily subjected to compressive loads. Hence, these members could be constructed of precast concrete material. However, steel is the preferred material for liners **14** since minimum compressive strain of the liners is desired to transmit relatively all of the expansion of the expansive concrete to the internal corners **20** of casing **12**, and to minimize forces directed to the internal surfaces **24** of the sidewalls of the casing.

It is apparent from the description of the embodiment illustrated in FIGS. 1A-B that it is essential that the expansion of the concrete be counter-acted by inwardly radially directed forces resulting from tension in the casing. Hence, it is not essential that casing **12** have a square cross-section, but any polygon shape would be acceptable. The number of arcuate liners required would correspond to the number of sides of the casing. Hence, the teachings of the present invention are readily adaptable to constructing any triaxially prestressed concrete member which has the external configuration of a regular polygon.

The alternative embodiment of the present invention illustrated in FIG. 2 utilizes a hollow casing or sheath **40** similar to the casing **12** illustrated in FIGS. 1A and B. However, the embodiment of FIG. **2** utilizes elongate liners **42** co-extensive with casing **40** having a generally W-shaped configuration. Specifically, elongate liners **42** have a central circular arc section and two outwardly directed planar sections **44** which intersect the interior corners **46** of casing **40**. Elongate liners **42** define a plurality of side channels **28** which are filled with non-expansive concrete which is allowed to cure. Central section **50** is then filled with expansive concrete material. A temporary curing hole **52** can be provided which is filled in later. Expansion of the expansive concrete **50** is restrained by elongate liners **42** which are in turn restrained by the interior corners **46** of casing **40**, much as in the embodiment illustrated in FIG. **1**. Hence, expansion of expansive concrete in central channel **40** is counter-acted by tension forces in the sidewalls of casing **40**, and the square configuration of the casing is retained to form a square, triaxially prestressed concrete member.

The embodiment of the present invention illustrated in the end view of FIG. 3 utilizes a thin steel tube **60** which defines an interior channel **62** adapted to receive expansive concrete. As an alternative, tube **60** could be formed from a close spiral of fine wires. Tube **60** is mounted interior of a co-extensive square or other polygon shaped casing **64**. A plurality of struts or blocks **66** are mounted between tube **60** and the interior corners **68** of casing **64**. One block **66** is provided for each corner **68**, and the blocks are co-extensive with the casing. Each block **66**, which can be either steel or pre-cast concrete, has a curved inner surface **70** adapted to contact an outer surface of tube **60**, and an opposite surface **72** in abutment with the internal

corner 68 of casing 64. When the interior 62 of tube 60 is filled with expansive concrete, expansion of that concrete is restricted by blocks 66 which are generally in contact with the internal corners 68 of casing 64. Hence, tension in the sidewalls of casing 64 prevents expansion of concrete to laterally or radially prestress the concrete. Axial prestressing results from the adherence of the expansive concrete to the interior surfaces of tube 60.

An embodiment of the present invention which utilizes removable forms to shape the concrete material is illustrated by way of reference to the end view of FIG. 4. An outer casing 80, illustrated as having a square cross-section but capable of having any polygon cross-section, is initially provided. A plurality of elongate generally pointed hollow caps 82, co-extensive with casing 80, are provided in each interior corner 84 of the casing. Temporary arch-shaped forms (not shown) interconnect the adjacent caps 82. Non-expansive concrete material is then poured into the plurality of side channels defined by the temporary forms. After the non-expansive concrete 86 is cured, the forms are removed, and the non-expansive concrete, together with caps 82, define an interior channel 88. Expansive concrete material is then poured in central channel 88 and a temporary curing hole 90 can be left in the center of casing 80. Due to the arch-shaped configuration of non-expansive concrete 86, expansion of the expansive concrete in central channel 88 is counter-acted by caps 82 in abutment with the internal corners 84 of casing 80. Hence, such expansion is prevented by tension forces in casing 80 as dictated by the principles of the present invention.

An alternative embodiment of the present invention which utilizes temporary bolts in conjunction with arc-shaped members to maintain the polygon configuration of an outer casing 100 is illustrated by way of reference to FIG. 5. A plurality of arcuate liners 102 co-extensive with the elongate casing 100 are provided in the interior hollow portion of casing 100. Each liner has a transverse dimension equal to one-half the width of the sidewalls of casing 100. Expansive concrete material is poured in the central channel 104 defined by the convex surfaces of arcuate liners 102. The lateral edges of the liners 102 adjacent the center of the sidewalls of casing 100 will tend to bow out the sidewall. However, such bowing action is restrained by means of bolts 106 which interconnect opposite sidewalls of casing 100. A plurality of such bolts 106 are provided along the length of elongate casing 100, and the bolts are staggered to eliminate interference between adjacent bolts at the centers thereof. Bolts 106 could be removed after the expansive concrete in central channel 104 has been laterally prestressed to give the resulting concrete member a smooth exterior configuration. However, if the aesthetics of the member are not in consideration, bolts 106 can be left embedded in the concrete. In order to further prevent expansion of expansive concrete in central channel 104, a spirally wound wire 108 can be provided co-extensive with casing 100. Spiral 108 may be embedded in the expansive concrete in central channel 104 and will restrict radial expansion thereof, reinforcing the prestressing provided by the casing 100.

An alternative embodiment of the present invention similar to that illustrated in FIG. 5 is illustrated by way of reference to FIG. 6. The embodiment of FIG. 6 utilizes bolts 110, which may be either temporary or permanent, connecting adjacent sidewalls of elongate casing 112. A plurality of such bolts 110 are provided along the length of casing 112. Spiral reinforcing wires 114 can also be provided to further prestress expansive concrete poured into the interior 116 of the elongate casing. The embodiment illustrated in FIG. 6 has the advantage that the expansive concrete material fills the entire hollow interior of casing 112, not requiring the use of non-expansive concrete or providing gaps in the interior of the casing.

While several preferred embodiments of the present invention have been illustrated in detail, it is apparent that modifications and adaptations of that embodiment will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention.

What I claim as new is:

1. A form for the construction of a triaxially prestressed concrete member comprising at least three side-defining elongate members, each side-defining member including an elongated planar portion and an elongated arcuate portion each having opposite side lateral edges in abutment with corresponding side lateral edges of the other, each side-defining elongate member being adjacent to two other of the said elongate members and joined thereto along adjacent lateral edges of the planar portions thereof so that the convex surfaces of the arcuate portions of the side-defining elongate members define an elongate chamber adapted to receive expansive concrete therein, said expansive concrete being confined by the side-defining members to prestress said expansive concrete.

2. A form as recited in claim 1 and additionally comprising non-expansive concrete intermediate the planar portion and the arcuate portion of each side-defining elongate member.

3. A triaxially prestressed concrete member comprising:

an elongate hollow casing having a substantially polygonal section defining three or more interior walls meeting at interior corners, said casing having a preselected length;

at least three elongate interior liners being of preselected length substantially co-extensive with the length of said elongate casing, each said interior layer having an arcuate section normal to its elongate length between opposite side lateral edges, each said liner being placed overlying one of the interior walls of the casing respectively, the opposite side lateral edges of each said liner in abutment with the interior corners contiguous with the associated wall to divide the hollow interior of said casing into at least three side sections defined by the concave interior surfaces of the liners and the interior walls of the casing, said elongate interior liners when located within said casing further defining a central section defined by the convex surfaces of the arch-shaped members;

non-expansive concrete material filling the side sections of the hollow interior of the casing; and

expansive concrete material filling the central section of the hollow interior of the casing.

4. A member as recited in claim 3 wherein the elongate hollow casing and the arcuate liners are constructed of steel.

5. A member as recited in claim 3 wherein the elongate hollow casing is constructed of steel, and the arcuate liners are constructed of pre-cast concrete.

6. A member as recited in claim 3 wherein the polygon section comprises a square section defining four interior walls, and wherein the liners comprise four elongate interior liners.

7. Apparatus for the construction of a sheathed, triaxially prestressed concrete member comprising:

an elongate hollow casing having a polygonal-shaped cross-section defining three or more interior walls meeting at interior corners;

means for defining an elongated central chamber within the elongate hollow casing, said central chamber being adapted to receive expansive concrete therein and inhibit axial expansion of said concrete to axially prestress said concrete, said chamber defining means including means connecting the central chamber to the elongate hollow casing at the interior corners of said casing, said connecting means adapted to substantially maintain a constant distance between the central chamber and each of the interior corners of the hollow casing so that the radial expansion of expansive concrete in the central chamber is restrained by the hollow casing to radially prestress said concrete.

8. Apparatus as recited in claim 7 wherein the cross-section of the elongate hollow casing is substantially square.

9. Apparatus as recited in claim 7 wherein the cross-section of the elongate hollow casing is substantially rectangular.

10. Apparatus as recited in claim 7 wherein the means for defining a central chamber comprises the convex surfaces of a plurality of elongate liners having an arcuate cross-section and a length co-extensive with the length of the hollow casing, one said arcuate liner corresponding to each of the interior walls of said casing respectively, each said arcuate liner having opposite lateral edges in abutment with adjacent interior corners of the elongate hollow casing.

11. Apparatus as recited in claim 7 wherein the means for defining a central chamber comprises the exterior surfaces of a plurality of liners co-extensive with the hollow casing, one said liner corresponding to each of the interior walls of the casing respectively, each said liner having opposite lateral edges in abutment with adjacent interior corners of the elongate hollow casing so the expansion of the expansive concrete is restrained by the hollow casing at the interior corners thereof to radially prestress said concrete.

12. Apparatus as recited in claim 7 wherein the means for defining a central chamber comprises an elongate thin-walled tube co-extensive with the casing, and a plurality of elongate blocks co-extensive with the hollow casing, one of the said blocks associated with each of the interior corners of the casing respectively, each said block having a curved surface adapted to contact the outer surface of the elongate tube and a second opposite surface adapted to be in abutment with the associated interior corner of the casing so that each said block substantially maintains a constant distance between the central chamber and the associated interior corner of the hollow casing.

13. Apparatus as recited in claim 12 wherein the blocks are constructed of steel.

14. Apparatus as recited in claim 12 wherein the blocks are constructed of pre-cast concrete.

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